Organization of African Intra-Plate Tectonics*

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Abstract

Arrays of fault blocks loosely aligned in belts often comprise fields of extensional basins and/or compressional uplifts within continents, for example in the forelands of orogenic belts (e.g. the late Paleozoic Ancestral Rocky Mountains in the interior western North America) or as failed arms of plate triple junctions (as in the case of Central African Rift System). Transfer faults occur within and between individual elements of such systems (as intra- and inter-basinal faults): they are fundamental features and are necessary to facilitate the kinematic integrity of the system. At their extreme, these transfer fault systems may be localized into inter-basin/uplift, regional 'mega-shear' systems that exploit pre-existing defects in the crystalline basement, pre-existing lineaments and terrane boundaries for example. The Central African Shear Zone or the here-proposed Southern Africa Trans-Africa Rift and Shear System are examples of such systems that cross-cut the continent. These mimic wrench fault systems in many details of their geometry, but insofar as they only accommodate the net extension or compression of the overall system, they do not necessarily display a consistent sense of offset or accumulate much net strike-slip offset at the continental level.

Introduction

The African basement was assembled by the end Precambrian as a collage of cratons with intervening mobile belts and sutures (Kroner, 1977). Control over structural trends through inversion and reactivation of the edges and features within those cratons by Phanerozoic plate tectonic-related processes is commonly documented (Versfelt and Rosendahl, 1989). Although this intra-plate deformation is a sideline of plate tectonics, it nevertheless is an important aspect of crustal architecture and a major habitat for important petroleum systems around the world. This contribution discusses more detailed aspects of structural systems in Sub-Saharan Africa and how they illustrate some principles of intraplate extension (Figure 1). It focuses on two types of systems, one associated with the 'failed arm' of the Gulf of Guinea triple junction during the opening of the Atlantic margin (Guiraud and Maurin, 1992; Fairhead and Green, 1989; Binks and Fairhead, 1992), and the other driven by Karoo extension in East Africa and the expression of foreland loading in front of the Cape Fold Belt system in southern Africa.

The examples we show here come from an Africa-wide compilation of tectonic elements in ArcGIS known as the Tectonic Fabric of Africa or 'TFA' (Figure 2). The compilation is an addition to the "Exploration Fabric of Africa" (http://www.efafrica.com/efaproject.html), aka the 'Purdy Project.' The dataset is based on original work by the authors and information available in the public domain, especially papers that display detailed structural elements that can be assembled into a kinematically rational structure map, such as Genik (1993), Bosworth (1994), Dou et al. (2007), and others. The elements are assembled into shapefiles of genetically related features. The structural elements files are supplemented by continental-scale compilations of potential field data and inversions thereof, e.g. the Marimba study from Dickson International Geosciences (DIGS) (http://www.digsgeo.com/MARIMBA.html).

CARS, CASZ, and WARS

The Central African Rift System (CARS) and its associated CASZ (Shear Zone) comprise the failed arm of the Gulf of Guinea triple junction in South America-Africa breakup. The inset in Figure 3 (from Fairhead et al., 2013) shows how the pole of rotation describing the motion of South America with respect to Africa migrated during 22 or so ma from a position off Morocco to a position north of Algeria. Early in the breakup, motion around the pole initiated NNE-SSW extension in the CARS system. By the time drift was well under way, with fracture zones developing as small circles around the more northerly pole, motion along E-W trajectories parallel to the CASZ was favored. This later motion was resolved in the continued opening of the many rifts in the CARS, such as the Nile, Melut, and Muglad Rifts. It also was compatible with opening of the Benue Trough and the Niger Rifts in the West African Rifts (WARS). The net effect is to separate the West African craton from the Nubian Craton, and to transcurrently move those two blocks relative to Sub-Saharan Africa in general, that is by the directions shown in the dark maroon, heavy arrows in Figure 3. Compared to ocean spreading in the Atlantic, these displacements of course are short-lived even though they are coeval in time to initial breakup of the continents.

In a broad sense, these displacements represent a reactivation along the Neoproterozoic Central African Orogenic Belt, while at the same time kinematically paralleling the Atlantic fracture zones. The small circle opening vectors more or less coincide with the east-west grain of the orogenic basement that separates the older Congo craton to the south and the Nigeria and Sahara cratons to the north. On the first order, the reactivation is manifest in the CASZ, as a trans-African continental-scale transfer fault that connects the terminations of the various extensional basins (Figure 3, main illustration). At the plate scale, one might think of the Cretaceous central African deformation as a ramification of an unstable triple junction that evolved to a stable two-armed system during the opening of the Atlantic. This failed arm of the triple junction distributed extension across the central African realm in a kinematically balanced manner.

A kinematic interpretation of the West African and Central African systems is shown in the main part of Figure 3. The Atbara Rift is located at the eastern terminus of CASZ. In conjunction with the Nile and Sudan (Melut, Muglad) rifts, it creates an extensional field south of the CASZ that is mostly uncompensated by smaller rifts on the north side, and thus a westward shift of the south side of CASZ relative to the north, as shown by the large red arrows. This renders a right-lateral sense of strike-parallel offset along CASZ. The shear negotiates a right step northeast the Muglad Basin, setting up a restraining situation where basement is brought to the surface. Farther to the west, a right bend in the fault sets up the Doseo pull apart basin. Beyond that, to the west, the trend persists seemingly all the way to the Atlantic coast. The Bongor and Doba Basins (and possibly others) on the north side in Chad partially compensate for the accumulated strike-slip motion, so that the offset may fall somewhat by the time it reaches the junction with the Benue Trough. Although the amount of offset appears to change along the system, the amount of northern extension is not large enough to reverse the sense of motion. Other faults that may participate in the system in Cameroon, however, may also mitigate the right-lateral offset. But because they cross-cut the Pan-African outcrop, it is difficult to determine their senses of offset. Additionally, to the south the Sanaga Fault zone might also contribute to complication of the total offset on CASZ. This tectonic synthesis could be quantified and tested by creating restored cross sections across its component elements, parallel to CASZ, and summing the results.

The Benue Trough forms the other arm of the CARS-WARS intra-continental system. It constitutes a cascading set of left-stepping bends and overlaps on an overall left-lateral shear. It transfers the opening at the Termit-Tenerife Basins in Niger into the triple junction region. The southwestward broadening of the Benue Trough may signify a slight clockwise rotation of the Northwest Africa craton with respect to the Nubian block, as shown by the divergence of the large red arrows. Together with the CASZ it records the net strain related to the triple junction expressed in the failed arm.

Blended Wrench and Rift Systems

A generalization of how such a system works is shown in Figure 4. The right side of Figure 4 is drawn to mimic the CARS/CASZ connections. This hypothetical situation assumes rigid blocks and no internal strain, i.e. no smaller scale structures within the blocks that would alter or redistribute the displacement between the blocks. The sense of relative offsets on the through-going shear depends heavily on the position and the magnitudes of the extensional basins surrounding it. And the offsets on the shear can reverse along length. In this hypothetical situation three rifts have nucleated along opposite sides of a crustal weakness that is destined to form the mega-shear. In the southeast, 2 km of total extension have accumulated in Rift 1 (R1) on the edge of a stable block. The blue pin point represents the end of the shear; block A remains fixed in this scenario. Two km of displacement shift block B to the west relative to block A and hence a right lateral offset develops between A and B as far west as the breakaway for R2. If R2 then opens with 15 km of extension, it shifts block C 15 km west relative to block A, and thus creates a left lateral offset between block B and C as far west as R3. The relative left-lateral offset between blocks B and C is 13 km (15 minus 2). If R3 opens a 22 km offset between B and D, the western end of the shear becomes a right lateral shear between blocks C and D, a total relative offset of 9 km (22+2-15). These are total or finite offsets. While motion is taking place, or if the rates of motion are different, then the relationships evolve during time and the strike-slip relationships can actually change with time.

Along the length of the mega-shear itself, typical *en echelon* strain-related deformation features as characterize wrench systems can develop. If the sense of offset reverses with time in the same place, left- and right-lateral styles can overprint each other, rendering very confusing local relationships. Among the most important structures possible are those developed at left and right stepping bends or overlaps that create restraining and releasing relationships. In Figure 4, for example, thrust features are shown at point S (for shortening) and extensional ones at E between blocks A and B, where the trend of the shear wanders one way or the other. A pull apart basin is shown in gray along the shear between blocks B and C in Figure 4: in this case a basin has opened on a releasing overlap. This simulates the Doseo Basin in Figure 3.

This intra-plate blending of structural styles need not be limited to extensional arrays. The left side of Figure 4 illustrates two intra-plate systems in comparison to the familiar wrench structural system: one in (a) which is like CARS, one for contractional environments in (b) which also shows left and right lateral relationships that depend on the displacements on component thrust faults, and for comparison, a typical through-going wrench or transform system in (c) where the fundamental kinematics are strike-slip. In (a) and (b) transfer faults connect block boundaries, and therefore the displacement on them is limited by the magnitude of the displacement on the contributing normal or thrust faults. In (c) on the other hand, the displacement on the through-going wrench fault is essentially unlimited, and therefore represents a plate boundary transform like the San Andreas fault system in North America. Figure 4c shows a single strand of the system, but in a typical transform several strike-slip faults contribute to a system. In the San Andreas system, for example, only part of the ~650 km of Pacific/North America relative motion is resolved on the San Andreas fault itself. Something like 195 +/- 15 km of net strike-slip offset is demonstrable on that single fault (Darin and Dorsey, 2012). The rest is focused on other faults in the system, many of which are just as dangerously seismogenic.

The power of recognizing the kinematic relationships between different elements of these systems lies in its predictive capability of locating cryptic or unknown pieces of the puzzle. Figure 5 illustrates this for Central Africa.

The background in Figure 5 is an excerpt from the TFI GIS compilation of the tectonic elements. Basement outcrop is shown in opaque pink, and the gross sediment thickness distribution as reds to yellows, greens, and blues: thin section is shown in cool colors, thicks in warm colors: red is the deepest basement. These data are from the MARIMBA Project total sediment isopach or TSI (Dickson and Odegard, 2013). The TSI is generated via spectral inversion of both gravity and magnetics data across large, overlapping windows. While providing stable, fairly good signal-to-noise values with depth accuracies of 5 - 10%, the output has low spatial (x-y) resolution because of averaging across, in this case, 40km x 40km windows. Faults from the TFI are plotted in blue while the components of the mega-shear are in red. The Tibesti lineament (Giraud et al., 2000) is shown with a query. Four numbered locations are shown where thick sedimentary section occupies locations where structural elements are not readily available for inclusion in the TFA. Hence, they are not included in Figure 3. Primary information, such as proprietary seismic data, may exist but are not readily available. These four locations are highlighted with numbers, and their relationship to the fault systems of the region are shown on the right. They could be thought of as frontier exploration leads.

Southern Trans-Africa Rift and Shear System

Southern Africa presents a similar but more complicated situation to that in Central Africa. Compilation of data in TFA in a similar fashion to CARS/CASZ has revealed a trans-African system we have dubbed STARSS, short for ‘Southern Trans-Africa Rift and Shear System’. STARSS broadly follows the suture system recognized by Burke et al. (1977). While Central Africa is dominantly a Cretaceous story, STARSS is composed of Karoo-aged Basins developed at least during the late Paleozoic to Triassic if not with earlier precursors, of features related to the Cretaceous breakup of Gondwanaland, and of overprinted Neogene extensional tectonics broadly identifiable as ‘East African Rifting’. Emplacement of the Cape Fold Belt was a major tectonic marker. The tectonic synthesis in TFA indicates that STARSS is composed of shears similarly to CARS but reactivated more repeatedly. Figure 6 is a basic compilation of the elements involved. The color polygons portray the various basement terranes of southern Africa projected under cover where necessary; the short blue lines within them represent the structural grain in the basement. Shown in pink are the bounding faults of well-known Karoo structural features mostly in Tanzania, Mozambique, Malawi, Zambia, and Zimbabwe. In red in Zambia and Namibia are well known lineaments, the important ones of which are named in subsequent figures. They are localized at terrane boundaries as well as within Pan African orogenic belts, the Damara belt in Namibia in particular is important to this study. In blue are subsurface features, faults and lineaments from various studies, to be described below. These are located in Namibia in particular.

Finally, in green in Figure 7 are the main fault systems and the lakes in solid blue of the East African Rift System (EAR), including some contemporary features in Botswana known as the Okavango Rift (Bufford et al., 2012). These are connected to more obvious East African Rift elements by way of lineaments in Zambia, Zimbabwe, and Malawi that appear to be currently involved in EAR reactivation. Their activity is primarily reflected in seismicity distributed across that region (Figure 7). Epicenters from recent earthquakes are shown in Figure 7, all are of low magnitude. Some of the data have been good enough to discern a few focal mechanisms, consistent with the NW-SE extensional direction of the Okavango rift and the multi-oriented extensional direction evident in the Malawi Rift (Ebinger et al., 1987; Delvaux et al., 1992; Chorowicz and Sorlien, 1992; Delvaux, 2001; Mortimer et al., 2016). One strike-slip mechanism in Mozambique is consistent with NW-SE or NE-SW slip on transfer faults in the EAR. Significantly, many of these focal mechanisms are clustered along known lineaments in the region, notably along the Zambia/Zimbabwe border in the western Zambezi Rift and elements of the Kariba Rift.

Figure 8 shows the STARSS components that are evident in outcrop. Uplift in East Africa is responsible for exposing the Karoo rifts there, and extensive mining interests have elucidated the basement blocks and their shear zones in much of the areas of Precambrian outcrop. Of import here are the Chimaliro Fault and the Mwembeshi shear zone (Versfelt and Rosendahl, 1989; Daly et al., 1989; Ring, 1994). In the west various lineaments in the Damara orogen (Omaruru, Otjihorongo, and Okahandra, for example [Corner, 2000]) disappear under cover as they proceed eastward so that their relationship to the Karoo of East Africa is hidden. Karoo is known from the Damara province, however, in the subsurface of a few wells, in outcrop along the north edge of the Damara belt, and from the Waterberg Basin which is faulted against Precambrian on the eastern edge of the inlier (Holzforster et al., 1999; Catuneanu et al., 2005). The gap between East and West African geology is filled by elements of pull-apart basins in NE Namibia (Kavango and Caprivi Basins) that are covered by Kalahari sands and Etendeka basalts, but which also have been recognized during exploration programs. Inversions of high-res magnetic data and studies using structural models (Figure 9) have been instrumental in identifying these basins. The trend of the EAR Okavango Rift system, which may reactivate elements of the Caprivi Basin, is crosscut by these extensions of the Namibian lineaments (Figure 6).

The Caprivi Basin was mapped by Instinct Energy Ltd., who outlined an exploration program for coal bed methane (Instinct Energy, 2011). Very little is known about this basin, but Instinct's map (Figure 9) shows a number of SW-NE trending faults bounded by a northwest facing master fault that trends in common with the master breakaway fault of the Okavango Basin. The trend is generally slightly less southerly than the Okavango.

The second feature in the gap, the Kavango Basin, is a new basin detected in an exploration program by Reconnaissance Energy International. Very few data are available from this part of Namibia (Figure 9), only surface mapping, potential methods studies, and water well boreholes being available. Hidden under Etendeka (Cretaceous) basalts and Kalahari surficial deposits, the Kavango Basin lies along the extension of the tectonic elements of the Damara (Neoproterozoic) fold belt and lineaments related to it. In the course of the exploration program, Cathey (2015) performed a Werner inversion of legacy high-resolution aeromagnetic data in northeast Namibia that revealed a deep basin in NE Namibia. This depth-to-basement inversion imaged a number of apparently extensional basement fault blocks beneath sedimentary fill ranging from 2 to 7 km (with an uncertainty of ± 10%). Seven profiles were then interpreted in terms of a theoretical sedimentary fill consisting of the Neoproterozoic, lower Paleozoic, Karoo, Cretaceous, and Kalahari sections known from the region. One of the profiles is shown in the upper left of Figure 10. Cathey calculated frequency spectra for the shallow Etendeka basalts (the red curve) and for the basement (black), shown in the uppermost left curves in Figure 10. These were then resolved into predictions of the depth to basement (red) and the base of the cover rocks (green) in the lower curves.

The senior author then constructed 'theoretical' structure sections parallel to those basement curves, using the top-of-basement as hard data (error on the depth is +/- 10%) and average regional thicknesses for a generalized stratigraphy to create cross sections, an example of which is shown in the lower section in Figure 10. Attempts were made to tie these sections and determine a notional direction of extension by applying restoration techniques in LithoTect™ structure modeling software from Landmark. The most successful attempts at that effort used a domino-structural style oriented in the NE-SW direction, as shown in the lower cross section in Figure 10.

Sections oriented in the E-W orientations proved to be more easily restored, suggesting that E-W is generally the profile view of the basin and thus the direction of extension. The restoration for the illustrated section is shown in the center of Figure 10. These models are necessarily generalized because geological control is remote from the region, but this restoration suggests something like 60 km of extension in a NE-SW direction. Note the depth to basement in this basin exceeds 7 km in places, and that the basin is elongate in the direction of extension parallel to the regional lineament/shear zone systems. This suggests a pull-apart like geometry for this basin, using the Proterozoic lineaments as strike-slip faults, all probably reactivated during recurrent extension during the late Paleozoic Karoo and the Cretaceous time periods of known southern African extension. This part of the STARSS trend is aseismic presently.

Putting all these cryptic pieces in the west together, end to end, we can see how the elements of STARSS link across the continent to the better-known Karoo Basins via established lineaments. Implied is the possibility that this fairway localizes a number of basement uplifts and potentially hydrocarbon-prospective extensional basins in much the same way that we see in CARS/WARS/CASZ. Figure 11 is a synthesis of these observations. In the upper left again is a representation of the regional sediment thickness in the color scale with basement outcrop portrayed in the opaque pink coloration. The description of this image is the same as that of Figure 5. Sediment-thick areas are shown in the reds and yellows, so that the Owambo Basin (OB) stands out prominently. It forms a breakaway on the northwestern corner of STARSS (Hoak et al., 2014). Additional basinal areas are designated with numbers that correlate to the numbers in the predictive structure map for STARSS on the lower right. The notation in the STARSS synthesis map is also the same as in Figure 5. The difference from central Africa here is that multiple shear zones are reactivated as mega-transfer fault systems connecting the extensional basins, so that in many cases both sides of the extensional basin are bounded by reactivated shears. This is the case for the Zambezi Basin (ZG), Waterberg Basin (WB), Kavango Basin (KB), or the Caprivi Basin (CB): all of these are localized between the strike-slip shear zones, which are shown in the red and green colors. The amount of offset on these transfer faults is defined by the amount of extension in the basin, or conversely the amount of extension in the basin is linked to the slip on reactivated boundary faults. Seismic data have not been available to us, but we would predict that seismic lines in northerly orientations across the basins would show steep bounding faults that may in some places look like exceptionally steep normal faults, vertical faults, or even steep reverse faults. More conventionally looking 60-degree dipping normal faults would bound the ends of the basins and within the basins in E-W oriented seismic lines.

The Owambo, Kavango, Caprivi, and the Zambezi basins presents frontier exploration opportunities. Other worthy areas of similar interest occur at the number 5, where the relationship of the Waterberg Karoo to the rest of the system is unclear but may in fact be similar. At 2, 3, and 4 there may be opportunities for exploration in locations that suggest more complicated relationships than are currently apparent.

In the east, in contrast, the Karoo Basins behave more like a set of conventional rift basins with intra-basement shears reactivated as transfer faults connecting them. A similar situation may be obtained in southern Angola, in the area of numbers 1 and 6, where elongate areas with thick sediment inversions extend perpendicular to the STARSS main trend. One interesting observation is that exposures of granulites and charnockites are reported from Malawi west of Lake Malawi (e.g. Huang, 2017 and references therein), in locations off the terminus of some of the shears (Figure 8). These rock types generally imply high-pressure petrogenesis and thus may represent elements of mid to lower crust that have been uplifted and exposed in post-Precambrian events. If these reports are correct, their location may indicate left-stepping situations on the right-lateral system as shown in Figure 11. The inset in the lower right shows a restoration of the offset on the EAR Malawi Rift (LM). The high pressure basement rocks are located where reconstruction of the Ruhuhu Graben (RG) on the east of the Lake connects to the transfer shear off the end of the Luangwa Rift (LB) on the west. The Maniaba Rift (MB) may be another example, although its counterpart west of the Lake is not apparent. Another interesting area of potential restraining relationships occurs in the area of the Barotke Basin (BB), where a left-step on the right-lateral system is also located. This is an area of steeply thinning section off the end of a prong of basement outcrop near the number 1 in Figure 11.

Multi-Shear Extensional Systems

Although the pattern of STARSS is complicated, the kinematics of such a system can be understood as a blend of structural styles in a similar way to the CASZ system. For southern Africa, this appears to be a blend of extensional systems with strike-slip systems in which multiple subparallel shear zones are connected by intervening extensional basins. Again, the extensional kinematics dictate the magnitude of offsets on the shears. We show a generalization of this type of system in Figure 12: an array of blocks (A through G) is connected by several subparallel pre-existing basement shears numbered 1 through 4. Where reactivated, these form either left- or right-lateral shears shown in green or red respectively, and where they are not reactivated we show them as dashed. Here we intend to show how opening of several rift basins 1 through 6 can reactivate older shears and utilize them as inter-basinal transfer faults. The offset generated on the shears is entirely dependent on the magnitude of the extension in the basins and, as they develop, on the timing of the activity of the normal faults.

Each of the shears is pinned at their west ends. South of all the extensional systems, we take block A as fixed. Observe that 8 km of extensional opening on Rift 1 in the southwest of the figure sets up 8 km of strike-slip motion focused on shear 2, between blocks A and B. In the center south of the figure, a right step from shear 2 to shear 1 transfers that 8 km of strike-slip motion from shear 2 to shear 1, thus preserving the same offset between A and B. As a result of that right step, a pull-apart basin is opened in the south-central part of the map, with again 8 km of extensional opening. Returning to R1, it trends northerly and cuts across shear 3 without differential opening, but if a second rift, R2 opens between shear 3 and 4, then shear 3 can be activated to separate block B from block C with an additional amount of displacement, in this case 5 km. Block C relative to A is thus displaced 13 km (8 plus 5) toward the east. If an additional rift opens between shear 3 and 4, R3 for example, with an extension of 4 km, then block D is shifted 9 km relative to block B, and 17 km (9+8) relative to A.

Looking at the northern tier of blocks in Figure 12, north of shear 4, rift R4 only opens with 1 km of displacement relative to A, so it opens a 1 km right-lateral offset in the corner near the pin on shear 4 between blocks E and A, but beyond R1 it becomes a left-lateral offset by reason of the opening of Rift 1, with 7 km of left-lateral offset, and 12 km of left lateral offset beyond Rift 2. Rift 5 opens 9 km of extension, so block F is displaced 10 km (0 plus one) to the east relative to A, and thus has 3 km of left-lateral offset relative to block C. If R6 opens an additional 9 km of extension, then total offset of G relative to A is 19 km, and therefore only 2 km of right-lateral offset occurs between G and D. In the northeast corner, we show a situation where shear 4 is not activated, and so the 2 km of offset between G and D is resolved as a thrust fault with 2 km of overhang between G and D.

As is the case with the simpler system in Figure 4, we assume not internal deformation for the blocks, so these are discrete displacements. But if there is internal deformation of a timing differential between displacements then the offsets can be quite variable and the resulting structures more complicated. The style of the structures can therefore differ wildly across these kinds of features.

Summary

In both central and southern Africa, roughly N-S aligned intra-plate extensional basins impart an E-W stretch to the Precambrian continental crust across the width of the continent. Their organization is governed on the first order by lineaments and terrane boundaries within the basement, which often function as inter-basin transfer faults when reorganized during Paleozoic, Cretaceous, and Neogene tectonic events. Structures that develop include easily recognizable but apparently in many cases only cryptically connected rift basins as well as structures that would more normally be associated with wrench systems, such as the Doseo Basin in CARS and the newly recognized Kavango, Caprivi, and potentially the Waterberg Basins in STARSS.

All of these basins present potential hydrocarbon resources that have been unevaluated. It is unknown even whether conventional or unconventional approaches to exploration are more appropriate (Granath and Dickson, 2017). Especially in the west where the source/reservoir intervals are substantially buried, the resulting resources may be appropriate for oil exploration or even for gas-to-power projects to support the growth of African industry over the next few decades.

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OUTLINE

- Introduction
- 'Structural systems' in Sub-Saharan Africa: CARS, CASZ, and WARS
- What they say about intraplate systems, especially extensional ones
- Southern Africa: the extent and composition of 'Southern Trans-Africa Rift and Shear System', "STARSS"
- Summary

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Bill Cathey at Earthfield Technology,
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The "Purdy Project " Exploration Fabric of Africa

Figure 1

Underlying project Tectonic Fabric of Africa of “TFA”

PURPOSE

-- Kinematically-based compilation of African continent-wide structural elements --

Rationale that there has not been a continent-wide tectonically focused data set

Progress in surrounding ocean basins and on continental margins has not been paralleled onshore

MEDIUM AND COMPONENTS

Compatible with Purdy Exploration Fabric of Africa (EFAfrica.com), **GIS-based**

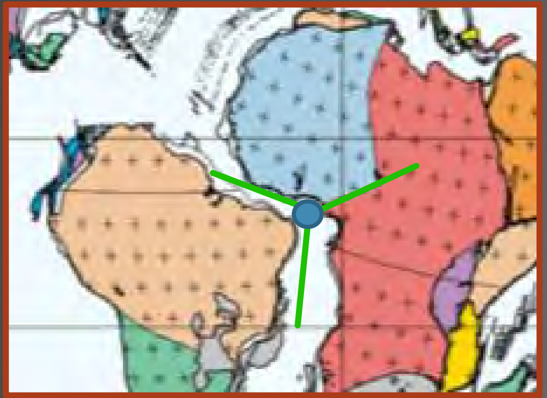
Literature plus proprietary material available to the authors

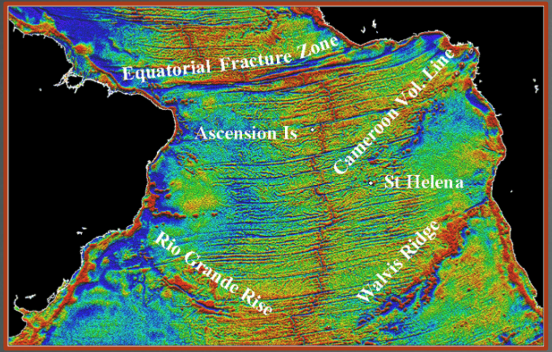
Original work

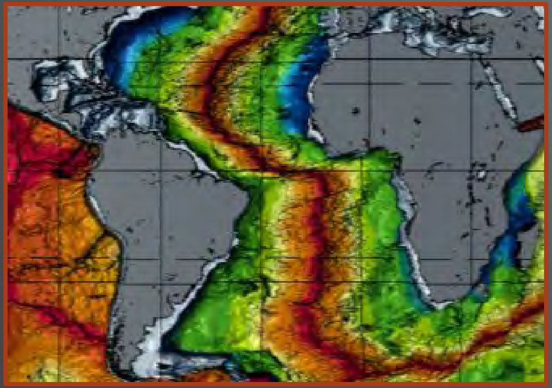
Continental-scale compilations of potential field data and its inversions

Figure 2

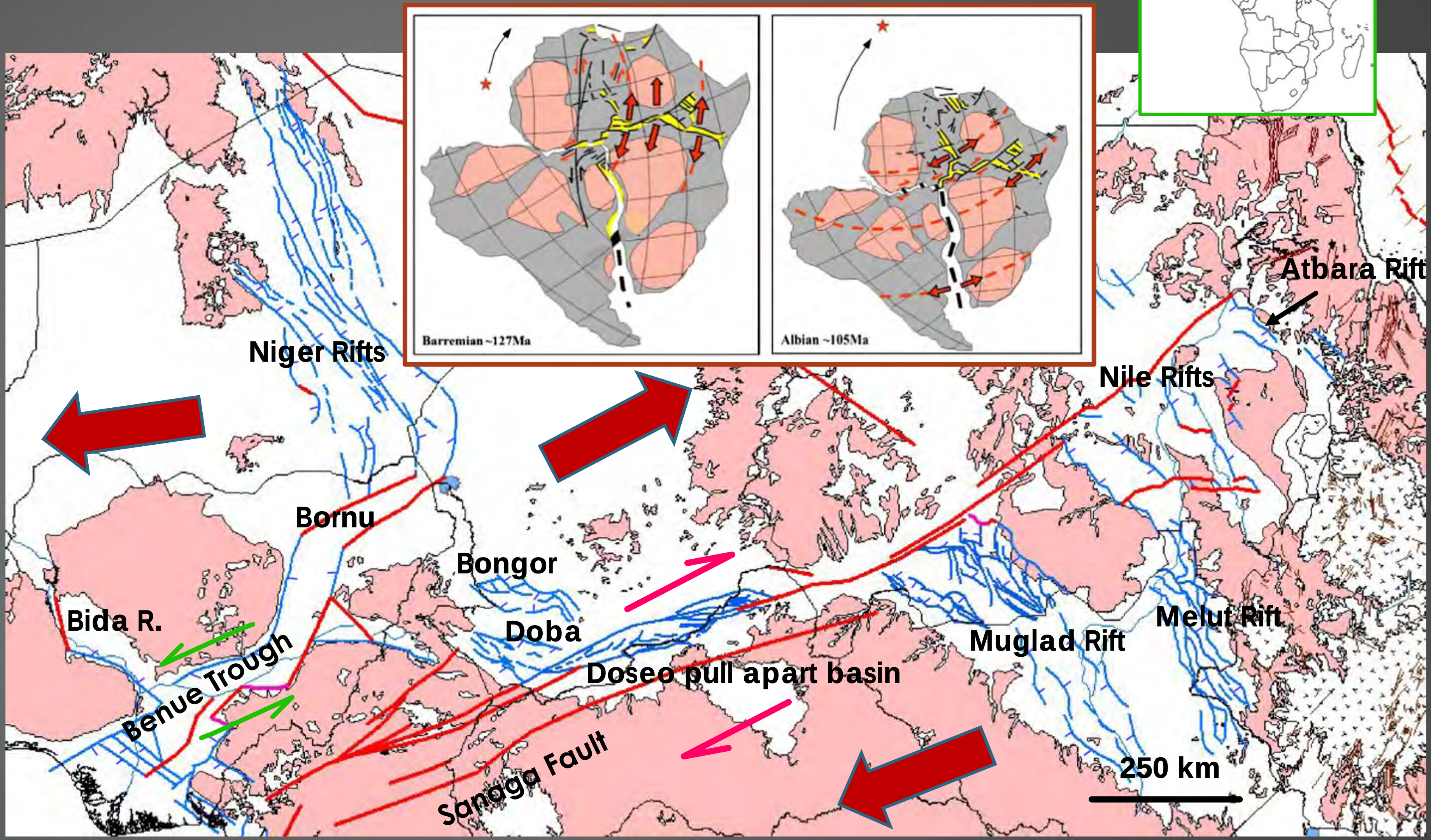
Elements of CARS/WARS & CASZ

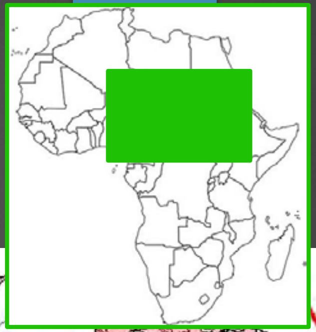






Fairhead et al. 2013 Tectonophysics

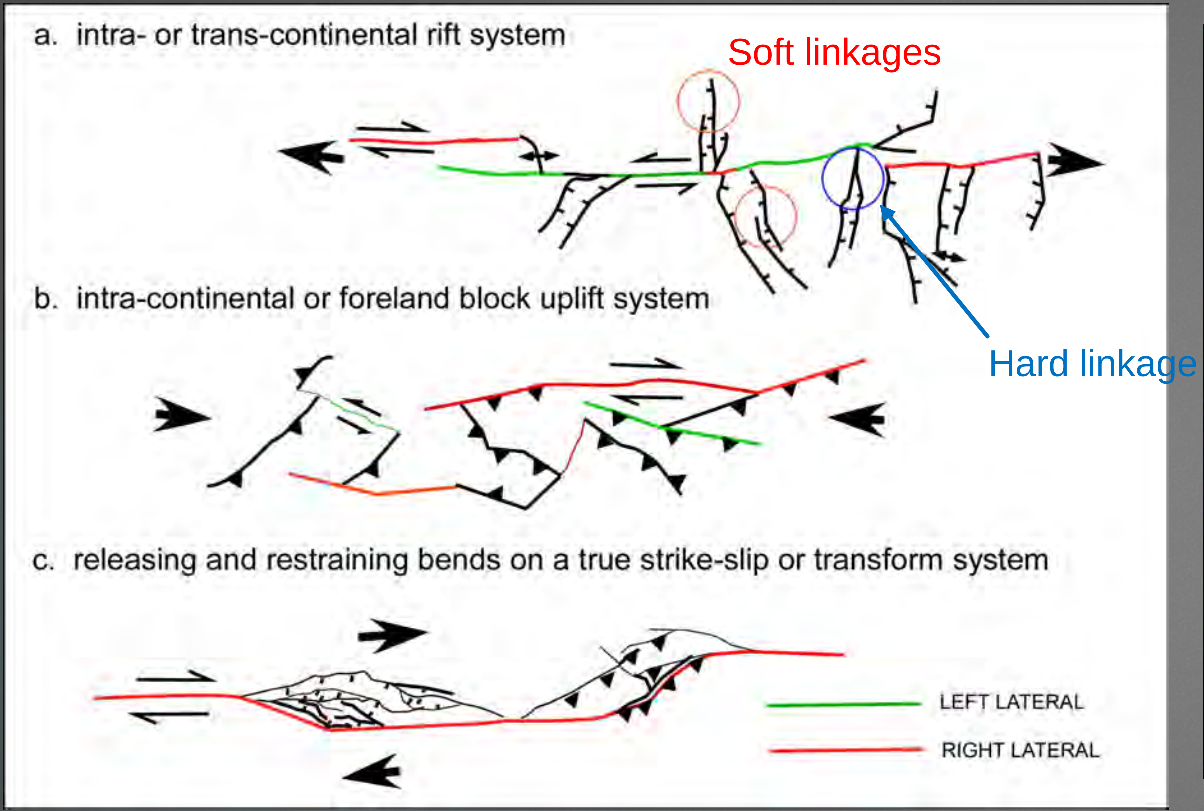




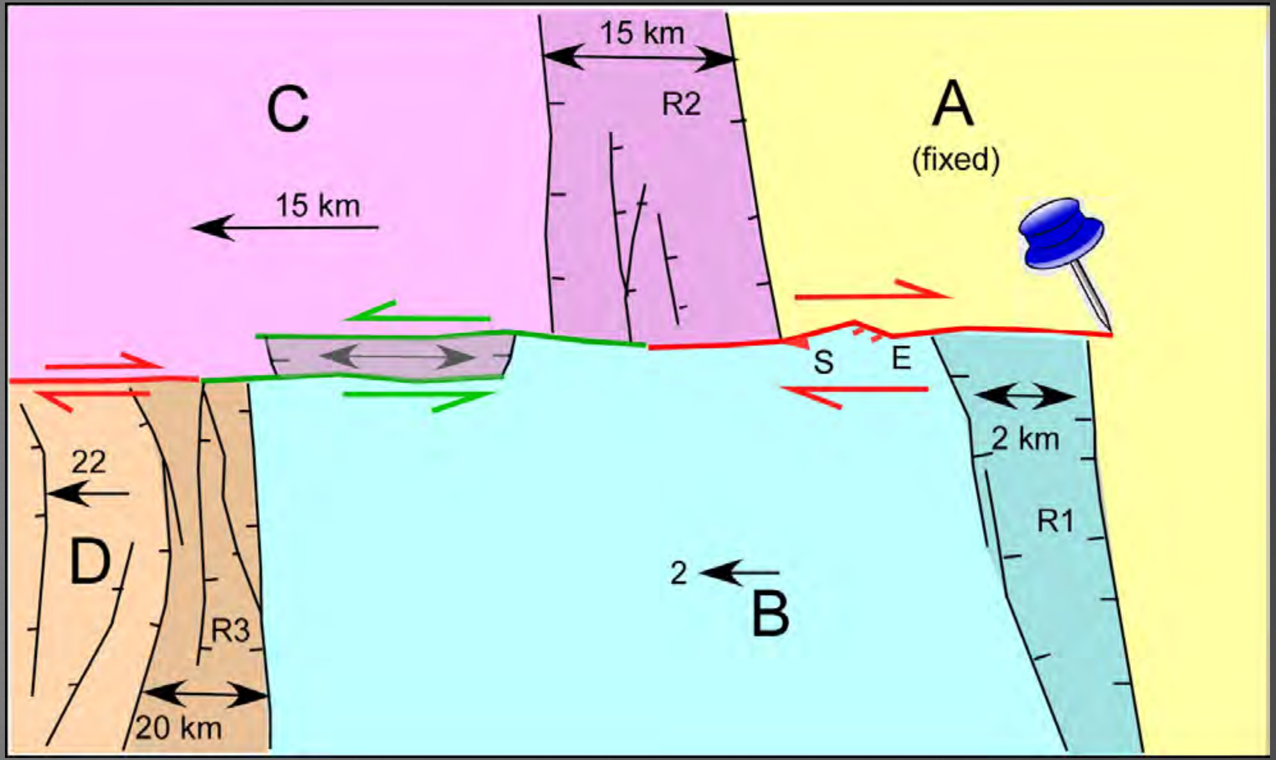
basement outcrop in pink

Figure 3

“Mega-shear” linkage systems



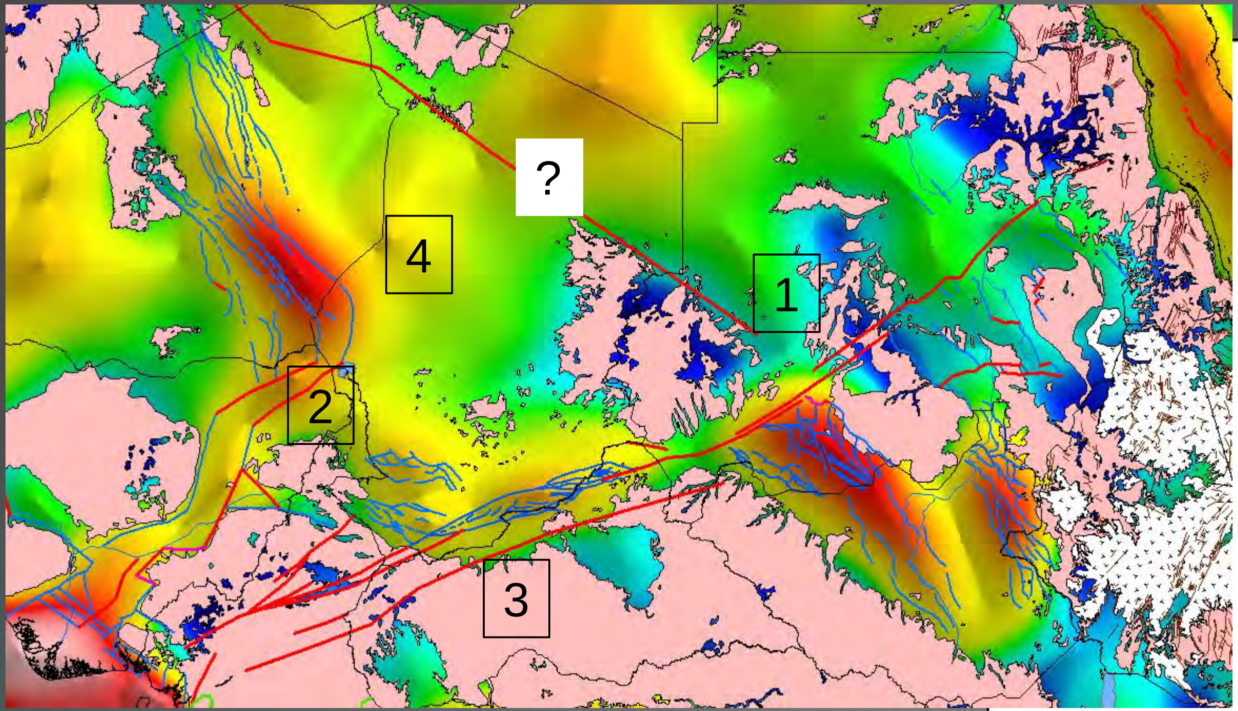
Varieties of intra-plate systems



Hypothetical illustration of reversal in sense of offset

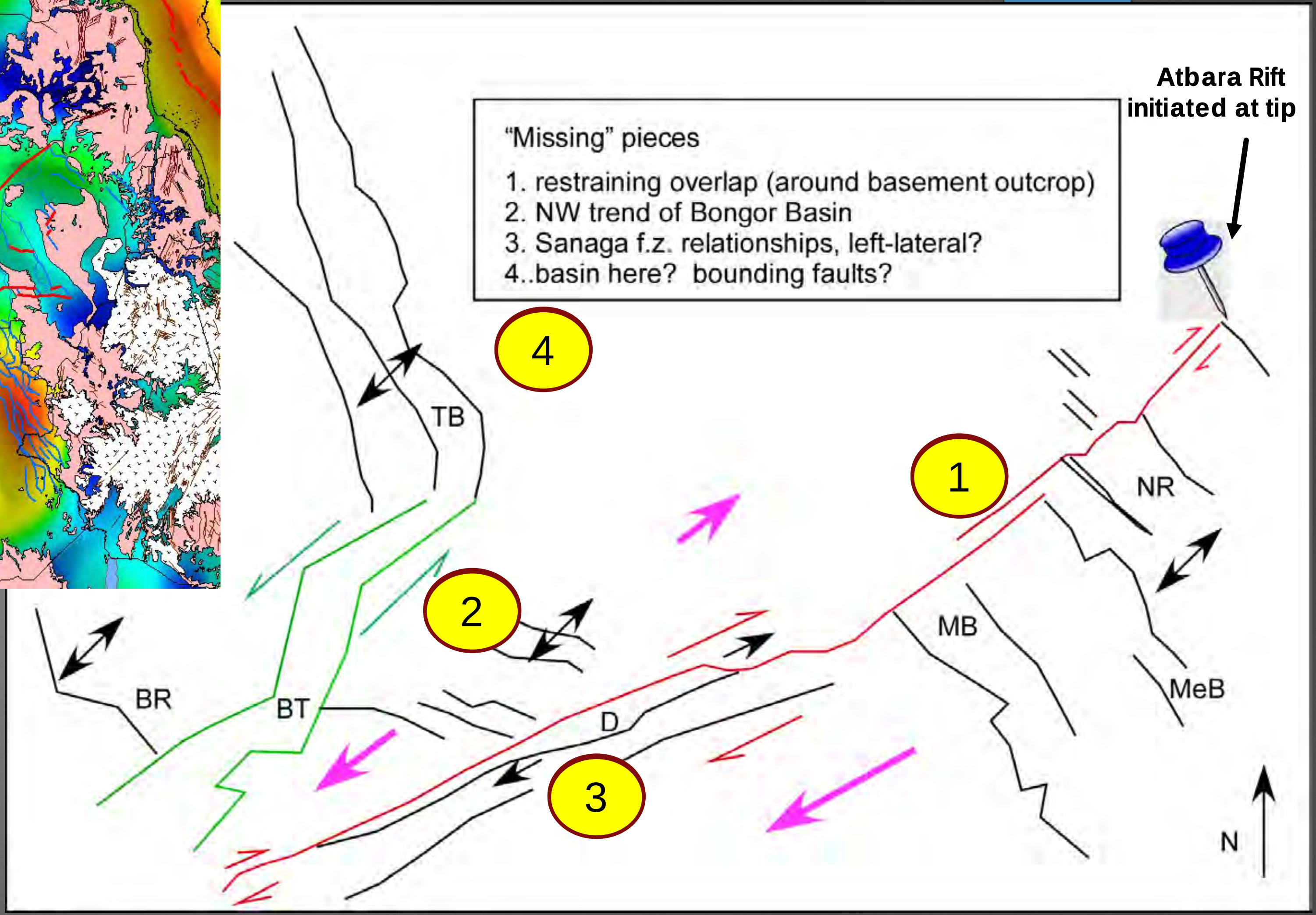
Figure 4

CARS/CASZ/WARS predictive synthesis



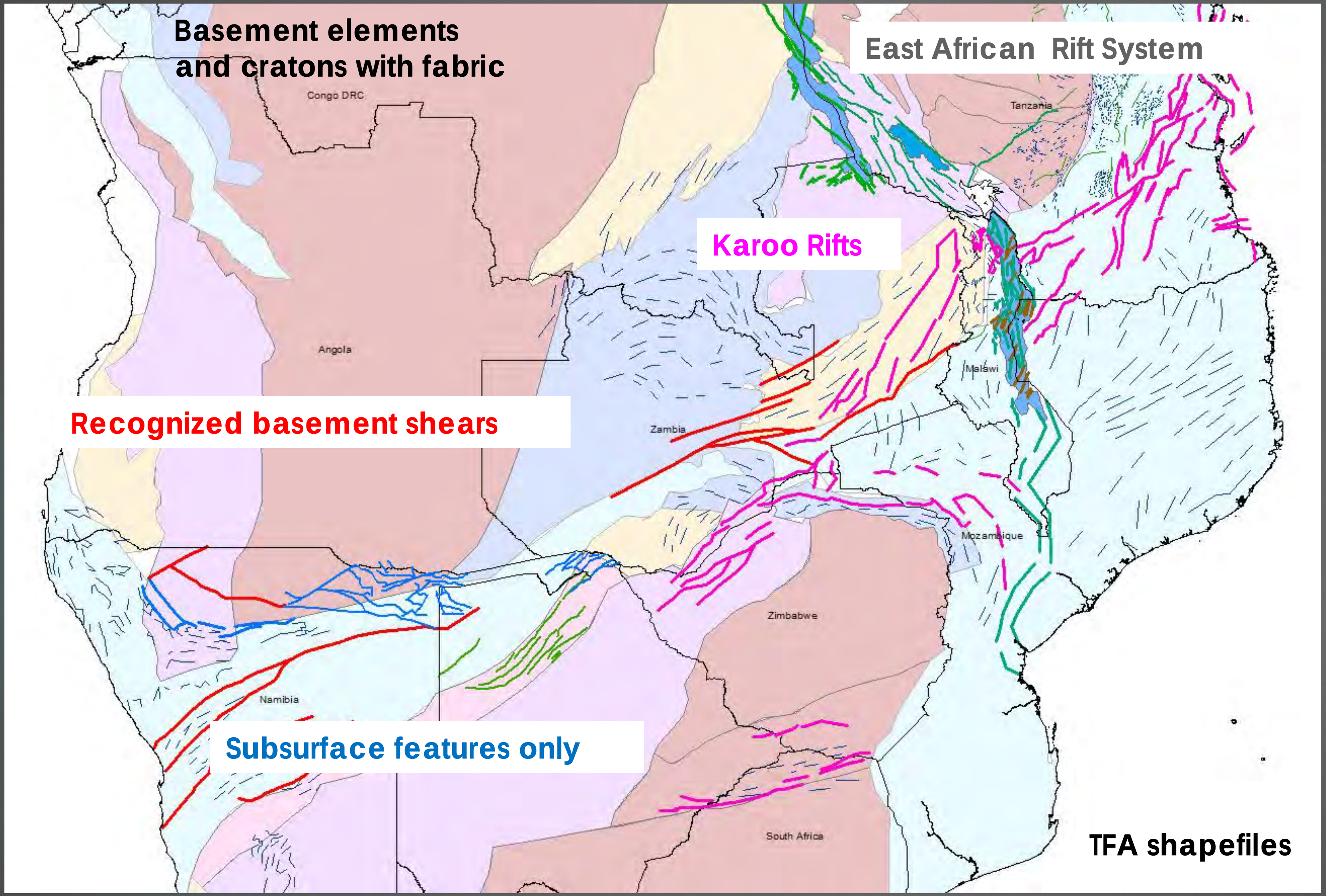
MARIMBA sediment thickness inversion

Figure 5



Transcurrent offset dies into Cameroon volcanic province, toward triple junction offshore

Southern African tectonic elements



- 1st order control edge of cratons
- Alignment across continent evident

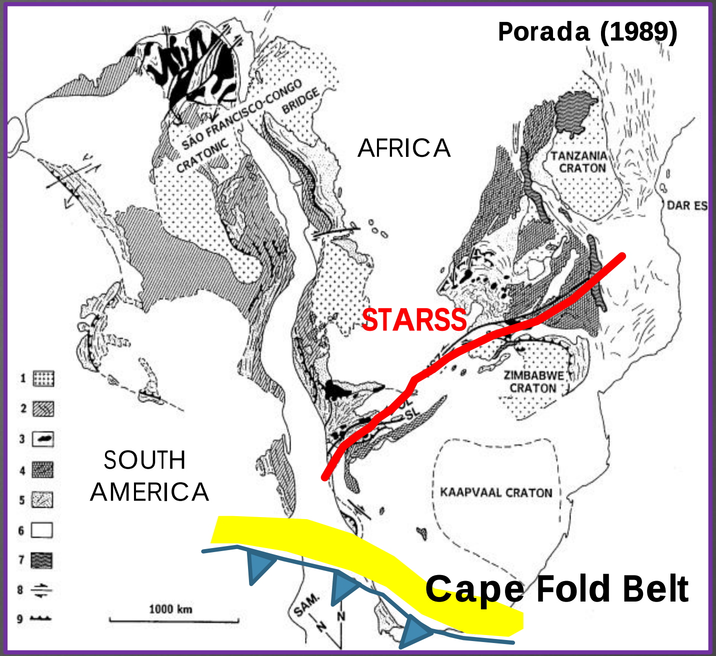
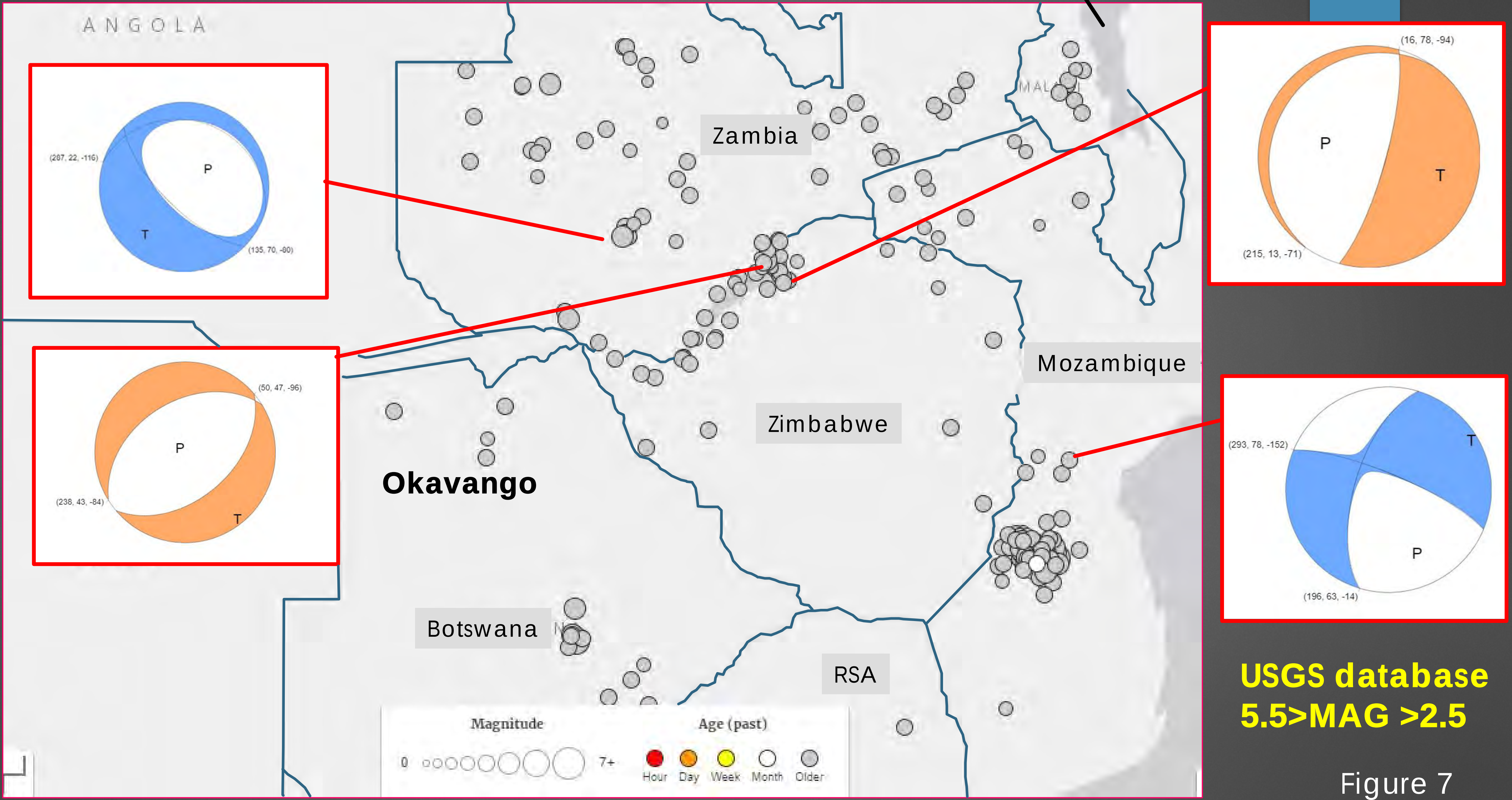


Figure 6

SEISMICITY 1975-PRESENT



USGS database
5.5>MAG >2.5

Figure 7

"Southern Trans-African Rift & Shear System" (STARSS)

exposed elements: basement shears & thrust belts, Karoo rifts

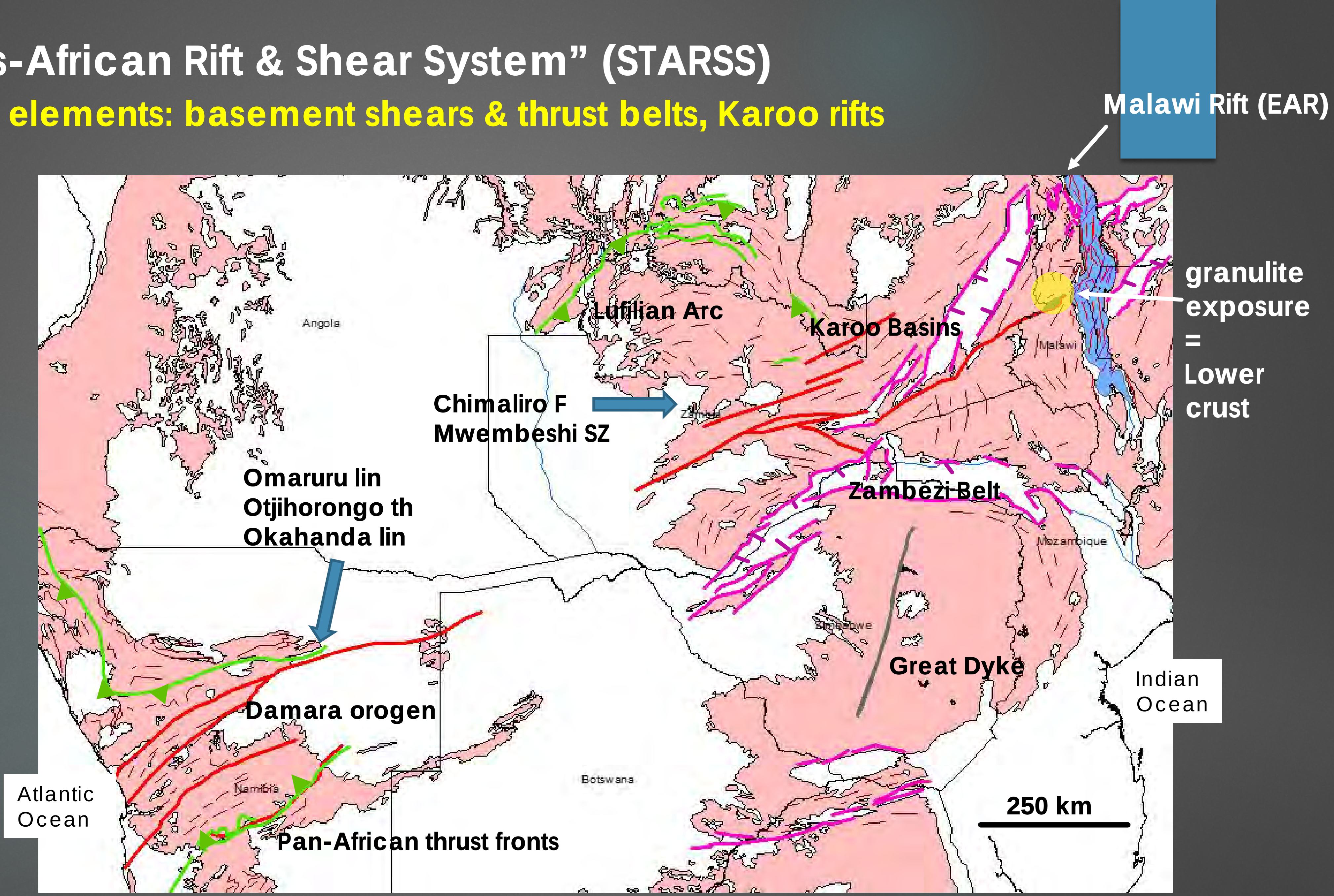


Figure 8

basement outcrop in pink

ArcGIS shapefiles

NEW ELEMENTS OF THE "SOUTHERN TRANS-AFRICAN RIFT AND SHEAR SYSTEM" 'STARSS'

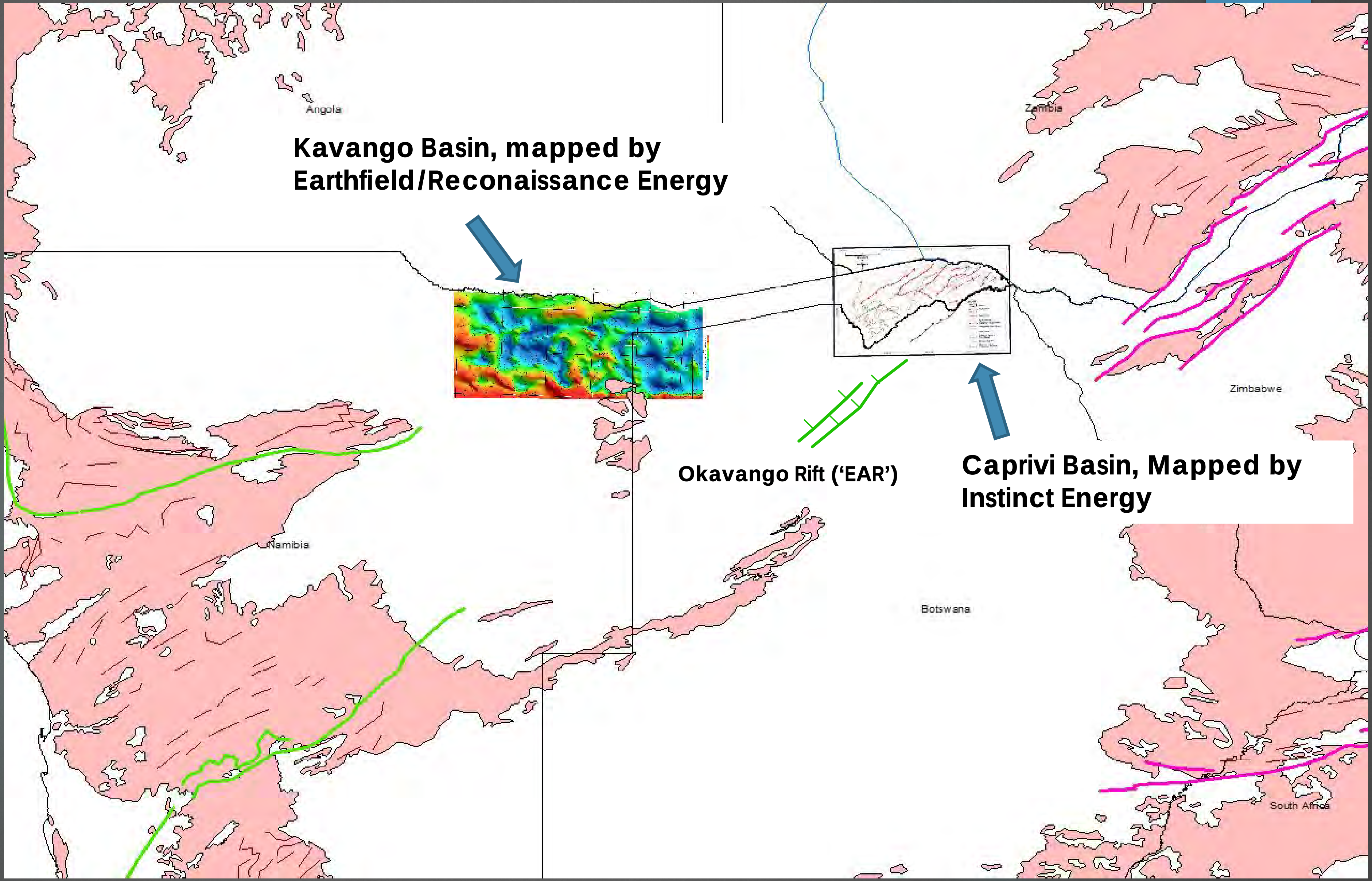
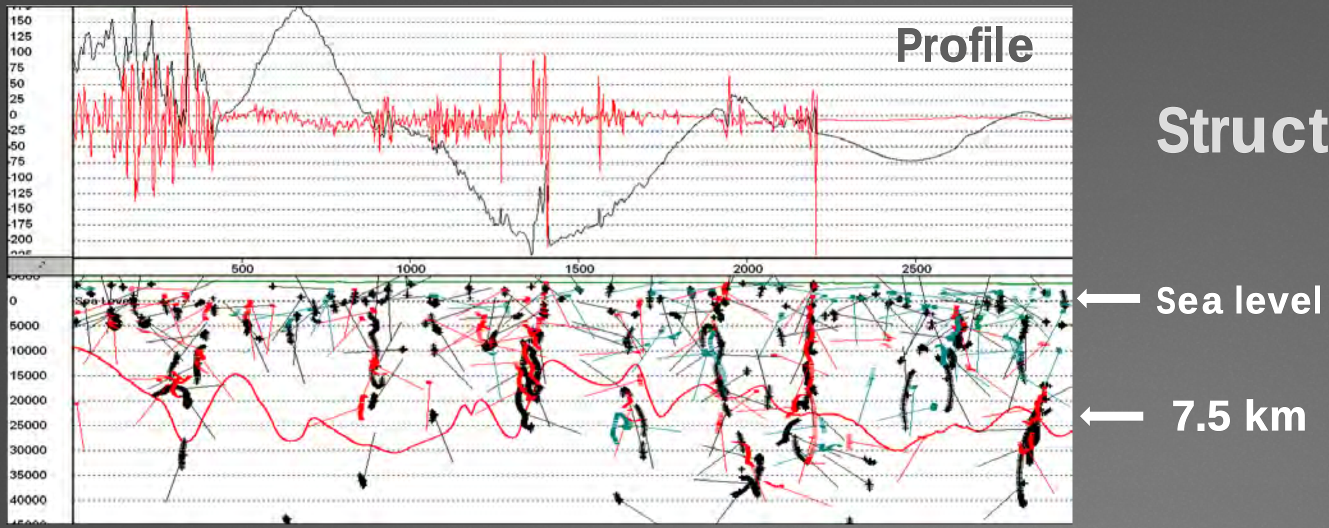
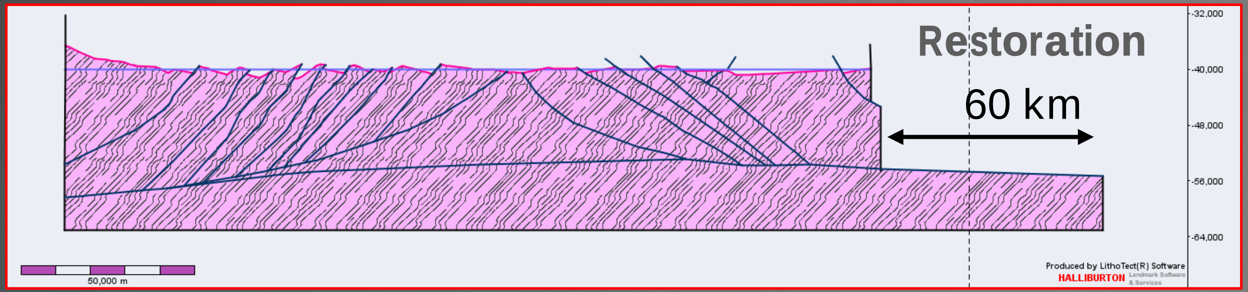


Figure 9

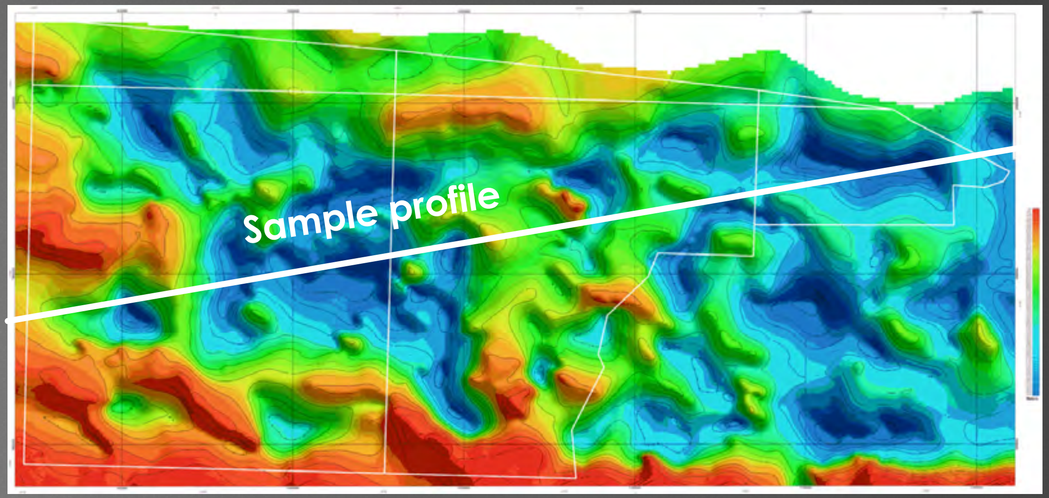
Figure 10

Structural modeling in Kavango Basin

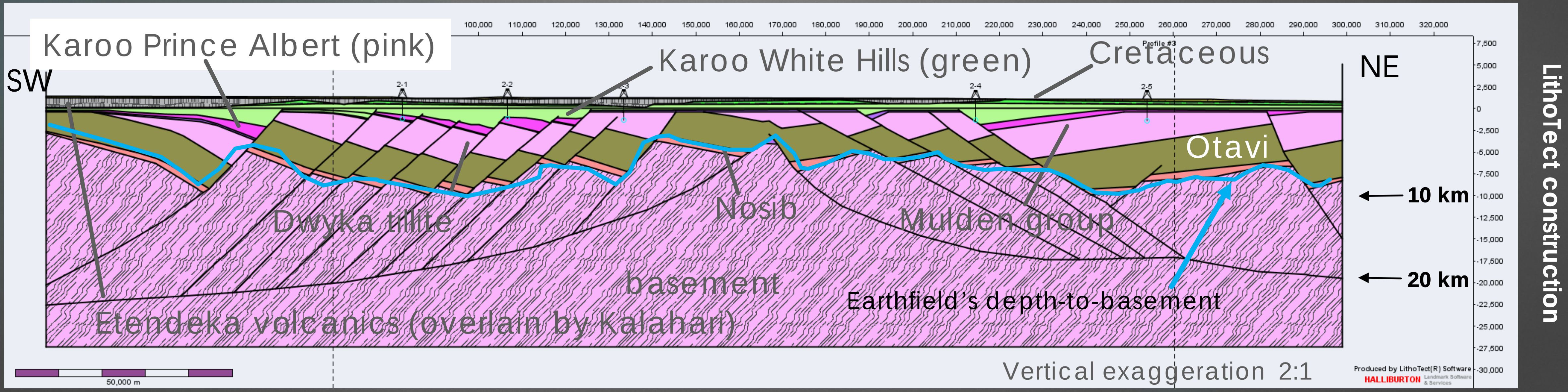




Depth to basement Werner inversion

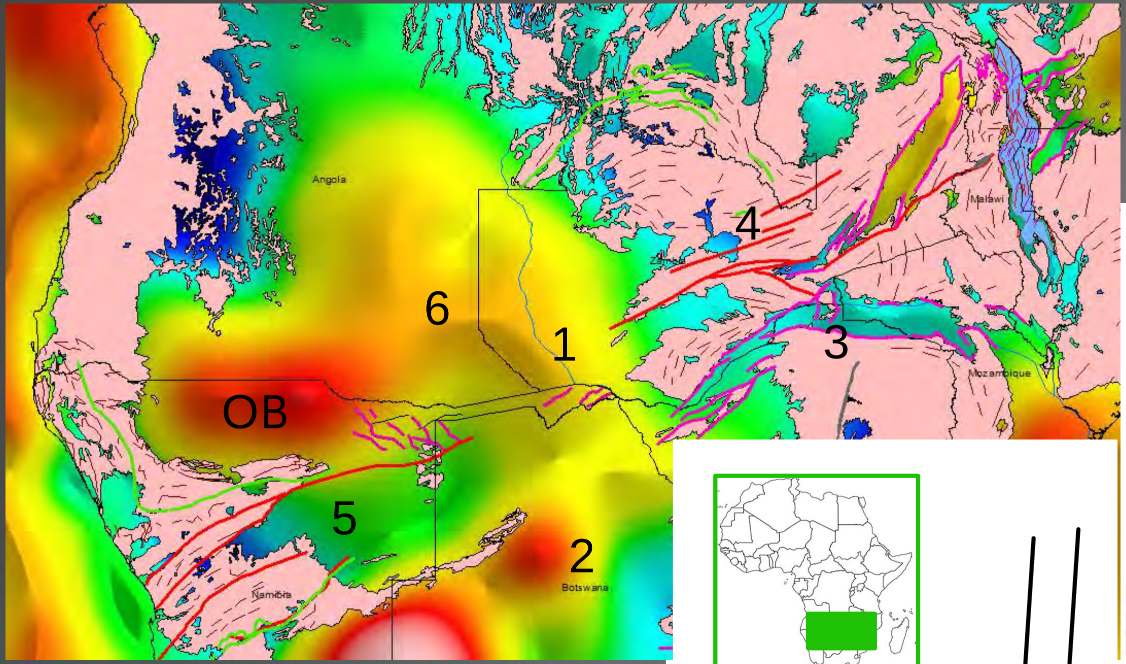


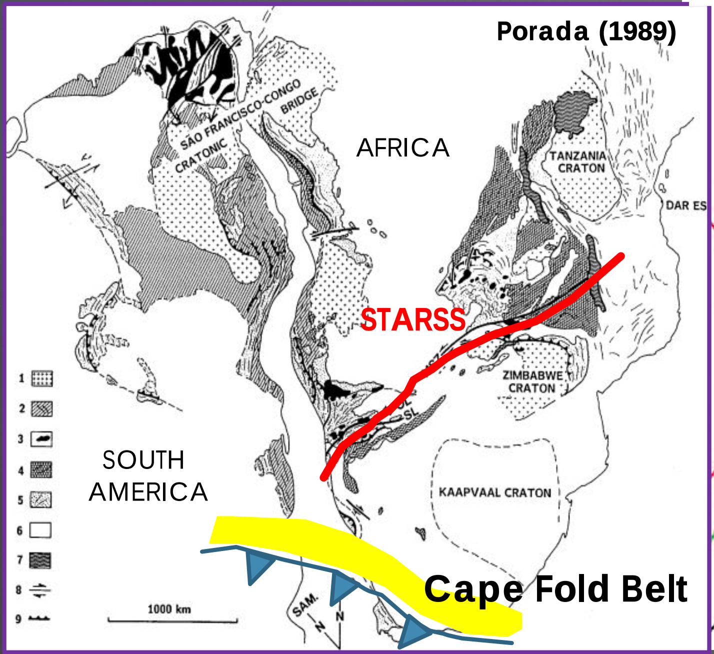
Bill Cathey, Earthfield Technology



STARSS predictive synthesis

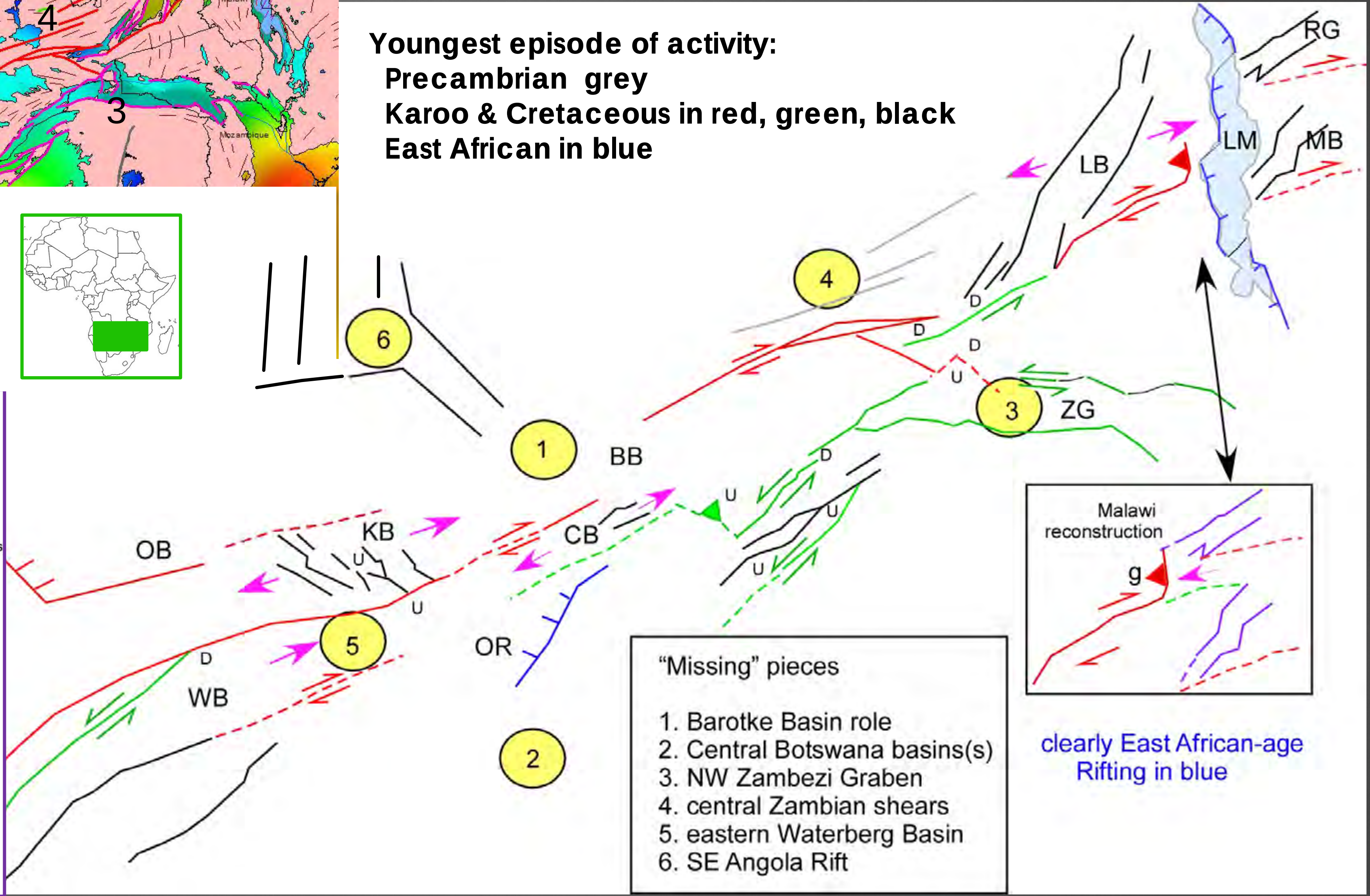
MARIMBA sediment thickness inversion





PREDICTIVE STRUCTURAL GEOLOGY

Youngest episode of activity:
Precambrian grey
Karoo & Cretaceous in red, green, black
East African in blue



Multiple shear-dominated extensional system